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- ABSTRACT TITLE

  Femtosecond Laser Cutting and Drilling of Tissue

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- ABSTRACT TEXT FOR ABSTRACT BOOK

The use of femtosecond lasers allows processing of both hard and soft tissue with extremely high precision and minimal collateral damage. Substantial advantages over conventional (>nanosecond pulses) laser drilling and cutting are realized by depositing the laser energy into the electrons of the material on a time scale short compared to the transfer time of this energy to the bulk of the material, resulting in increased ablation efficiency and negligible shock or thermal stress. A temperature rise of only 2°C was measured in dentin with femtosecond pulses, while comparable drilling with nanosecond pulses resulted in a 50°C increase.

• FULL ABSTRACT TEXT

Background:

Tissue removal with conventional (> ns) lasers is by a thermal mechanism. The laser provides very rapid local heating resulting in melting, boiling and ablation of the irradiated area. Unfortunately, this heat is not fully localized within the laser beam as conduction can occur to surrounding tissues. Conduction and thermal shock resulting from the large stresses associated with thermal ablation of a localized hot region surrounded by relatively cold material result in collateral damage to healthy tissue. Collateral damage can be reduced somewhat by operating at low repetition rate or by introducing auxiliary cooling agents. However, at low repetition rate the rate of material removal is too small to make the laser procedure viable and introduction of cooling agents significantly modifies both the laser and tissue properties.

Materials:

Enamel, dentin, bone, nail, heart, fused silica

Methods:

The above materials were cut and drilled with a laser over a pulsewidth range of 100 fs to 10 ns. We determined ablation thresholds and rates as a function of pulse fluence and duration. Optical and electron microscopy were used to characterize the incident surface and cross sections of the materials. Using a thermal camera, we measured the temperature rise in a bulk section of dentin irradiated by 300-fs and 1-ns pulses.

Results:

Dramatically cleaner cuts at higher efficiency and with negligible collateral damage were made by using femtosecond pulses as compared to nanosecond pulses. Substantial melting and fracture is evident in the nanosecond cuts, whereas the femtosecond cuts leave the surrounding material in essentially its original state. A 1-mm slice of dentin ablated at a rate of 10 μm/s increased in temperature by over 50°C after a 1-min exposure to 1-ns pulses, but by only 2°C with 300-fs pulses.

Discussion:

With subpicosecond pulses, material is removed by a fundamentally different mechanism: expansion of a multiphoton-initiated plasma from a very thin layer (≈0.5 μm) with little or no heat transfer to the material lattice. The ablation threshold decreases as the pulse duration becomes shorter, requiring less energy per pulse to remove material. This results in an extremely clean ablation "crater" (no melting or slag) and no thermal shock to the surrounding material.

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